

GUARDRAIL COMMON SENSOR



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LESSONS LEARNED FROM THE EARLY STAGES OF DEVELOPMENT OF THE GUARDRAIL COMMON SENSOR FOR THE RADICAL REDUCTION OF CYCLE TIME

J. Daniel Sherman

Nine key participants from the government and prime contractor were interviewed to identify important lessons learned from the early stages of development of the Guardrail Common Sensor. In addition to in-depth interviews, U.S. Army Communications and Electronics Command (CECOM) historical documents, unclassified government reports, and other public sources were reviewed for information regarding the system's development. The management of the system development deviated from normal acquisition processes in several important ways. These are presented and the implications for flexibility in the acquisition process are discussed.

The history of the U.S. Army operation of Special Electronic Mission Aircraft (SEMA) began during the Vietnam War. The need for signal intelligence (SIGINT) was significant during the Vietnam conflict, and as a consequence, improving the capability of these systems became an important Army priority.

GUARDRAIL DEVELOPMENT PRIOR TO COMMON SENSOR

In 1970, based on the successful development of ground-based systems in Vietnam, the National Security Agency (NSA) under the guidance of its director, Admiral Gayler, initiated the development of an airborne communications intelligence

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(COMINT) system with more advanced capabilities. In February 1971, the contract was awarded to Electronic Systems Laboratories (ESL), a division of TRW, for the development of what would be known as Guardrail I (Swainston, 1994).

During the early 1970's, Guardrail I was followed by a rapid succession of Guardrail systems that included Guardrail II, III, and IV. Guardrail I-IV (GR I-IV) achieved their operational requirements and were each produced on schedule and within budget. These early systems were

"The TDOA capabilities of GR/CS would give the United States a technology advantage over any potential enemy."

procured by NSA as Quick Reaction Capability (QRC) programs. They were designed as theatre level assets that led to a long-term requirement for Guardrail as an Army Corps level asset. In early 1976, the Guardrail V (GR-V) program was conceived and ESL continued the pro-

gram as prime contractor. The GR-V program was planned as a cost-effective, second-generation technology insertion program. In 1977, as a result of the Intelligence Organization and Stationing Study, responsibility for the Guardrail program was transferred from NSA to the Department of the Army, Electronics Command (ECOM, later to be Electronics and Communications Command, CECOM; Rawles, 1989).

Unlike the contracts for GR I-IV, the GR-V program had significantly increased formal data requirements in the areas of logistics, the qualification test program, spare parts program, quality assurance program, and software documentation. However, GR-V was still classified as a

limited production urgent system. In this sense, while GR-V lost some of the skunkworks-like characteristics of GR I-IV, it still retained the authorization to proceed as an urgent QRC program with significantly reduced oversight requirements (Moye, 1986; D. Swainston, personal communication, August 3, 2001).

THE GUARDRAIL COMMON SENSOR PROGRAM

In 1982, while the improved GR-V systems were being completed, a concept began to emerge for an advanced system that integrated other COMINT and electronics intelligence (ELINT) systems with Guardrail. This would be known as the Guardrail Common Sensor (GR/CS). It would combine the Advanced Quicklook (AQL) and the Communications High Accuracy Airborne Location System (CHAALS) with Guardrail to form a corps level signal intelligence system with an integrated platform and a single ground processing facility (R. Sciria, personal communication, August 9, 2001).

Development of the Quicklook ELINT system (the predecessor to AQL) had begun in the early 1970s. With GR/CS, a new generation of Quicklook would be developed that employed the technology known as Time Difference of Arrival (TDOA). This technology utilized triangulation from multiple aircraft to obtain location coordinates for the emanating source of a radio signal. The TDOA capabilities of GR/CS would give the United States a technology advantage over any potential enemy. However, in order to achieve the integration for the GR/CS system, the AQL would require miniaturization due to weight and space limitations. The contractors for the Advanced

Quicklook were UTL Corporation in Dallas (for development) and Emerson Electronics and Space Division (ESCO) in St. Louis (for production). The second system that was integrated into GR/CS was the CHAALS precision COMINT location system. This geolocation system for communications emitters utilized both the TDOA technology and Differential Doppler technology, and International Business Machines (IBM) continued as the contractor (CECOM, 1994; Jette, 1996).

The basic operational concept behind GR/CS was to authorize one GR/CS system per aerial exploitation battalion in the military intelligence (MI) brigade of each corps. A standard system would consist of 12 aircraft that would fly operational missions in sets of two or three. The ground processing for GR/CS would be conducted in the integrated processing facility (IPF). The IPF would be the control, data processing, and message center for the overall system. It consisted of four 40-foot trailers with 28 operator stations. Interoperable data links would provide microwave connectivity between each aircraft and the IPF. Reports would then be transmitted to the Commanders Tactical Terminals (CTT). The CTTs would be located at up to 32 designated intelligence centers and tactical operations centers. The automated addressing to CTT field terminals would provide automated message distribution to tactical commanders in near real time. The system later added a satellite Remote Relay System (RRS). With this system, intercepted SIGINT data could be transmitted to any location in the world (CECOM, 1987, 1988; Hall, 1990; U.S. Army, 1994). The first GR/CS was completed in 1991 and throughout the 1990s development continued with an

intensive program of technology insertion through pre-planned product improvements.

LESSON 1. A HIGH TECHNOLOGY READINESS LEVEL REDUCES RISK

A number of important factors contributed to the success of the Guardrail program. One of the most significant factors that influenced budget, technical performance, and particularly schedule in each phase of the Guardrail development was the level of technology readiness or maturity. When the program started in the early 1970s, ESL had already developed an extensive base of relevant knowledge among its engineering staff in its laboratories. This knowledge had developed through their experience with ground-based remote COMINT systems in Vietnam. In addition, at ESL, other Department of Defense (DoD) programs provided a synergy in the development of the technologies that would be required for Guardrail.

The extensive base of expertise at ESL (and later CHAALS expertise at IBM and AQL expertise at UTL Corporation) was only one contributor to the level of technology readiness. Another important contributor was the development strategy that was first instituted at NSA and adopted by ESL, and later adopted by the Army program offices. This development strategy was multidimensional, but one

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key element was a focus on minimizing technological risk and making design decisions based on technological maturity. However, this strategy included a program of systematic pre-planned product improvements based on technology insertion. The technologies in areas such as integrated circuits, direction location find-

ing technology, signal processing technology, computer hardware and software were evolving rapidly during this period. The Guardrail program offices and ESL believed that as each successive system was completed and fielded, the next system could be incrementally upgraded as a new generation Guardrail system with

more advanced technology (R. Ohlfs, personal communication, August 6, 2001).

The laboratories at CECOM also played an important role during Guardrail development. G. Morris (personal communication, August 1, 2001) of CECOM noted that in supporting the CHAALS and the Advanced Quicklook programs the CECOM laboratories helped solve numerous technical problems that allowed these systems to mature sufficiently for integration into the Guardrail Common Sensor.

The strategy of minimizing technological risk and making design decisions based on technological maturity worked well throughout the 1970s and 1980s. However, both C. Dubusky (personal communication, August 6, 2001) of the Army GR/CS program office and D. Swainston (personal communication, August 3, 2001), retired

ESL program manager, believed that the program began to deviate from this strategy in the 1990s. With GR/CS System 2 the technological envelope began to be pushed too far, too soon. This resulted in increased levels of technological risk, and subsequent problems with cost, schedule, and technical performance. This is perhaps a lesson in organizational learning itself. Each successive generation of managers (both government program office and prime contractor) must learn from the successful and failed decisions of preceding programs. In the case of GR/CS System 2, what had been learned in the past in terms of development strategy seems to have been forgotten.

LESSON 2. UTILIZING AN OPEN ARCHITECTURE

C. Dubusky (personal communication, August 6, 2001), chief engineer at the government project office, and H. Redd (personal communication, August 7, 2001), ESL field representative, observed that one of the problems projects encounter in areas where the core technologies are advancing rapidly is potential for the system to be obsolete before it is ever fielded. Because Guardrail was becoming increasingly software dependent with each successive generation, to address this problem the Guardrail government program office and ESL instituted two initiatives. The first was the application of real time tactical system processing architecture that was based on the use of international standards and the use of a seven layer Ada protocol. The second initiative was the Advanced Tactical SIGINT Architecture initiative that employed a

unified architecture that was bus oriented and employed all Ada software. Thus, the architecture and the software standards became the basis for the system, not the vintage of computer hardware. As new computer and bus technology were introduced, so would the method of adapting to the established standards. In this way, as computer hardware rapidly evolved, the software for successive generations of Guardrail could be rapidly adapted.

It should also be noted that this approach relied heavily on commercial off the shelf components (COTS). In fact, by the time GR/CS System 1 was being produced, 66 percent of 1176 components were commercial off-the-shelf. Furthermore, 91 percent were common with other systems. In essence, a key component of the acquisition strategy could be described as evolutionary acquisition. A core capability is fielded with a modular open structure and the provision for future incremental upgrades. Each successive upgrade would then occur as a block of pre-planned product improvements (R. Ohlfs, personal communication, August 6, 2001; D. Swainston, personal communication, August 3, 2001).

LESSON 3. THE IMPLEMENTATION OF A PROGRAM

In the context of the Cold War, and under conditions of rapid technological advancements, the normal acquisition processes were viewed to be inadequate by the Guardrail program office. H. Redd (personal communication, August 7, 2001), who worked for the government program office before moving to ESL, indicated that based on the failed experience of the

Communications and Electronics Forward Looking Flying Lancer (CEFLY Lancer), program office staff were convinced that a radically different acquisition strategy was needed. This strategy focused on schedule performance and consisted of several important components. First, and most importantly, was the approval of a Quick Reaction Capability program (QRC program). Given the urgent nature of the program, and the fact that top Pentagon officials were convinced of the criticality of the schedule, the program office was able to obtain a letter signed by a four-star Army general and a four-star admiral (NSA) approving the QRC program. This letter was later referred to as the “eight-star letter,” and it allowed the program office maximum flexibility to modify and bypass existing acquisition processes.

For example, one of the factors that contributed to the schedule and cost problems with the CEFLY Lancer was the requirement to comply with extensive military specifications. S. Pizzo (personal communication, August 28, 2001), an engineering manager with the government program office, observed that the Guardrail program office understood that the great majority of these elaborate specifications would not be critical to Guardrail’s performance, maintainability, reliability, etc. However, to comply with such requirements would result in vastly reducing the ability to use existing *off-the-shelf* equipment and components. This would affect schedule and cost. In other words,

“As new computer and bus technology were introduced, so would the method of adapting to the established standards.”

the incremental benefit associated with many of the specifications could not be justified based on the schedule and cost implications. With the approval of the QRC reduced cycle time program, numerous non-critical milspecs were eliminated or modified.

In addition, the program office understood that the standard Army devel-

"...while engineering development activity was included in the production contracts, it was not funded in the usual way as cost plus incentive fee contracts."

opment process with the usual milestones and approvals would reduce their ability to field the system in the time parameters that were needed in the Cold War environment. In light of this, the QRC program allowed Guardrail to be funded almost completely as a production program. In actuality, there was engineering development

occurring as the program progressed, but it was funded under the production contracts. In essence, the acquisition strategy was to begin with the baseline Guardrail system and then evolve the system through blocks of pre-planned product improvements using mature, but state-of-the-art existing technology (C. Dubusky, personal communication, August 6, 2001). In this way the scheduling ramifications associated with the standard Army acquisition process would be reduced. Of course, such an approach would not be advisable for programs with extensive engineering development requirements or large production runs. In the case of Guardrail, this approach worked because the technology was mature, considerable COTS components

could be used, and each system was comparatively unique or customized.

Former ESL Guardrail program manager, T. Black (personal communication, August 3, 2001), observed another important ramification associated with the use of production contracts. Almost all of the contracts were fixed price or fixed price plus incentive fee contracts. This forced the contractor to be extremely accurate in cost estimating prior to program start. Because of ESL's depth of expertise in all of the major technologies, cost estimating was generally very accurate.

As noted previously, while engineering development activity was included in the production contracts, it was not funded in the usual way as cost plus incentive fee contracts. C. Dubusky (personal communication, August 6, 2001) of the government program office observed that this approach to the acquisition strategy on the part of the government resulted in disciplined cost containment.

LESSON 4. WHEN THE SCHEDULE FOR FIELDING IS URGENT

S. Pizzo (personal communication, August 28, 2001) of the Guardrail program office observed that the assumption that competition in defense contracting universally results in superior performance in terms of cost, schedule, and technical performance may be incorrect. Competition should predictably achieve the desired results under most conditions. However, there are conditions under which the normal competitive process in government contracting will not result in the highest level of technical and schedule performance.

Guardrail seems to have been one of those programs.

When the schedule for fielding is urgent, the technology is evolving rapidly, and the defense contractor that developed the first (baseline) system is by far the leading firm in terms of relevant system specific technical expertise, then a sole source contract may be required. In the case of Guardrail, the initial contract for Guardrail I was competitive. Thereafter, the contracts were sole source to ESL as prime contractor (with the other pertinent subcontractors). This resulted in several important advantages for schedule and technical performance.

First, the sole source contracts for the sequence of systems following Guardrail I allowed for requirements to be set through dialogue. The usual situation would be for the requirements to be specified prior to a request for proposals (RFP). Thus, requirements would be set in advance. In the case of Guardrail, ESL engineers and government engineers worked very closely to develop specifications for each successive system within the general requirements specified by the Training and Doctrine Command (TRADOC). However, TRADOC generally deferred to the judgment of the program office, and this allowed for specifications to be developed through joint dialogue between engineers at ESL and the government (D. Swainston, personal communication, August 3, 2001).

R. Ohlfs (personal communication, August 6, 2001), former chief systems engineer at ESL, suggested that this approach worked well because ESL could effectively identify requirements that might not be cost effective or requirements that could adversely affect the schedule.

Thus, the dialogue tended to influence the process so that design decisions approached the optimum.

Both G. Morris (personal communication, August 1, 2001) of CECOM and D. Swainston (personal communication, August 3, 2001) concluded that TRADOC contributed to the requirements stability and funding stability of the program. This was very advantageous to Guardrail because it allowed the engineers to work in an environment that minimized dysfunctional change. When changes or new capabilities were presented by TRADOC, the Guardrail program office would assess the technical feasibility and cost implications and introduce the change in the next successive generation of pre-planned product improvements. However, TRADOC basically deferred to the judgment of the technical experts at CECOM and ESL as to what was and was not cost effective or technically feasible. In this way, the program benefited from an environment of stability.

“...the dialogue tended to influence the process so that design decisions approached the optimum.”

LESSON 5. ACHIEVING EFFECTIVE INTEGRATION FOR THE COMMON SENSOR

From the beginning of the Guardrail program, internal integration at ESL had been managed very effectively. ESL had utilized a project-matrix structure with a functional engineering organization. The functional areas included laboratories, and the organization was based on engineering specializations. The Guardrail program

office obtained engineers from the various functional areas. These assignments were typically full time until an individual was reassigned to another project. In addition, the laboratories or functional groups would provide technical support to the Guardrail program office on a task-by-task basis (R. Ohlfs, personal communication, August 6, 2001).

The program office had a team of assistant program managers that each man-

"To keep the program on schedule, program evaluation and review technique (PERT) was used extensively, and schedules were reviewed weekly on a task-by-task basis."

aged a major subsystem or functional area. One of the former ESL program managers, T. Black (personal communication, August 3, 2001), indicated that the team of assistant program managers met on a near daily basis because of the high degree of interdependency among the various systems. To keep the program on schedule, program evaluation and re-

view technique (PERT) was used extensively, and schedules were reviewed weekly on a task-by-task basis. Even before concurrent engineering became common, ESL was applying the basic processes in the Guardrail program (R. Ohlfs, personal communication, August 6, 2001).

Prior to Common Sensor, external coordination with the various subcontractors was minimally complex. As prime contractor, ESL assumed responsibility for system integration. With the advent of the Common Sensor and the addition of the CHAALS and AQL systems, integration increased in complexity. ESL and the Guardrail program office at Ft. Monmouth

developed interface control documents to specify the necessary interfaces with equipment being developed and produced by IBM, ESCO, Beech, Unisys, UTL Corporation, and other contractors.

S. Pizzo (personal communication, August 28, 2001) and G. Morris (personal communication, August 1, 2001) on the government side and T. Black (personal communication, August 3, 2001) on the contractor side observed that the interface between ESL and the government program office was much like an integrated product team (IPT). Long before these came into vogue in the 1990s, ESL and the Guardrail program office were implementing this type of interorganizational project coordination. George Morris (personal communication, August 1, 2001) observed that when IPTs were formally implemented in the 1990s, they tended to be leaderless groups and decisions tended to be reached by consensus. In some instances this worked well, but in other cases the consensual decision making simply did not work. G. Morris (personal communication, August 1, 2001) noted that in the 1980s, prior to the formal implementation of IPTs, the interorganizational teams in the Guardrail program were not leaderless. Typically, the government program office retained final decision authority. However, as a general practice, there was deference to the judgment of those who had the greatest technical knowledge on a particular matter. This approach seemed to work more effectively than the leaderless IPT approach.

In general, the government program office and ESL effectively managed the system integration. However, there was one significant exception. This was the management of the weight for the Beech

aircraft during GR/CS System 3 (CECOM, 1992). This was a miscalculation that Beech, ESL, and the Guardrail program office did not discover until System 3 was being tested. This miscalculation resulted in the need to re-engine the aircraft, and this led to serious delays in the completion and fielding of GR/CS System 3 (R. Ohlfs, personal communication, August 6, 2001; Rawles, 1990). The problem could have been avoided if Beech, ESL, the other contractors, and the Guardrail program office had been adequately monitoring the weight problem. If discovered earlier, the replacement of engines on the Beech aircraft could have then occurred concurrently so that the original schedule could have been achieved.

In any case, G. Morris (personal communication, August 1, 2001) of CECOM concluded that integration is facilitated when there is a single prime contractor with multiple subcontractors, and the prime contractor assumes total responsibility for integration. As Guardrail moved into the Common Sensor program, the CHAALS and AQL systems were furnished to ESL through the government program office as government furnished equipment (GFE). ESL had responsibility for integration, but the relationships were ostensibly different because IBM was not a subcontractor to ESL for CHAALS. Neither were UTL Corporation or ESCO subcontractors to ESL for AQL.

Like G. Morris (personal communication, August 1, 2001) and S. Pizzo (personal communication, August 28, 2001), of the Guardrail program office, observed that systems with multiple prime contractors have more complex integration problems. Just as the Navy Battle Group Passive Horizon Extension System

(BGPHEs) suffered from extensive integration difficulties due to multiple government project offices with multiple prime contractors, as GR/CS began to move in a similar direction, integration became increasingly problematic.

LESSON 6. A CORPORATE CULTURE CAN AFFECT THE SUCCESS OF A PROGRAM

Given the large learning curves associated with system specific technical knowledge on complex defense systems, continuity in personnel can be a very important contributor to schedule and technical performance. This is not to say that a continuous infusion of new talent is not necessary. This, too, is essential to any engineering organization. However, managing turnover and retention is clearly a problem of optimization.

T. Black (personal communication, August 3, 2001) and D. Swainston (personal communication, August 3, 2001) observed that at ESL a core group of engineers worked on the program for a number of years. In fact, as many as 100 engineers worked on the Guardrail program at ESL for a duration of 15 years. Since each Guardrail program was successive, there were no gaps in time where a large amount of turnover and new hiring had to occur. This continuity clearly facilitated organizational learning and the enhancement of the extraordinary base of expertise at ESL.

T. Black (personal communication, August 3, 2001) and R. Ohlfs (personal

“...systems with multiple prime contractors have more complex integration problems.”

communication, August 6, 2001) suggested that several important factors contributed to ESL's ability to retain such a talented cadre of engineers. First, ESL was very competitive in terms of salary and benefits. This allowed the TRW division to attract and retain highly talented individuals.

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Secondly, the corporate culture created an environment that made ESL a very collegial and enjoyable place to work. From the very beginning, William Perry (who would later become Secretary of Defense) tried to create a very close knit, cohesive

climate at ESL. Even as the company grew larger and became a division of TRW, ESL still maintained a highly cohesive and supportive culture.

A third factor that characterized ESL was a corporate culture that emphasized flexibility. To illustrate, in the early 1980s, R. Ohlfs (personal communication, August 6, 2001) had considered leaving ESL. His reasoning was based on the fact that he was spending an inordinate amount of time on functional management tasks, and he missed spending the larger proportion of his time on purely technical work. He discussed his sense of diminishing job fulfillment in terms of management responsibilities with the president of ESL, Don Jacobs. Jacobs' response was characteristically atypical. He simply said that ESL needed to create a work environment where talented and self-motivated people are free to do what they do best. As a consequence, the company introduced a type of a dual career ladder where exceptional engineers could

progress in a technical track and provide technical leadership in the company without being burdened with managerial responsibility. As a consequence, R. Ohlfs (personal communication, August 6, 2001) stayed another 17 years.

A fourth and perhaps most important factor that contributed to retention was that the engineers working on the Guardrail program had a collective vision for where the technology could eventually go. Furthermore, they understood the national importance of their work in the context of the ominous threat of the former Soviet Union. The combination of these important factors contributed to the continuity in the base of expertise that was successfully maintained at ESL.

THE IMPLEMENTATION OF A PROGRAM

Clearly not all of the observations from the Guardrail program would apply to the development of other defense systems. However, consistent with contingency theories of management, these observations may be useful in the identification of determinants for the implementation of a program with a radical reduction in cycle time, and the identification of important characteristics of those programs.

Figure 1 summarizes necessary conditions and important characteristics of programs that require radically reduced schedules based on the observations and lessons learned that are presented in the preceding sections. Such programs are only necessary when the time parameters for the development, production, and fielding of a system are critical. These conditions typically arise when an emerging threat is evolving rapidly, and in

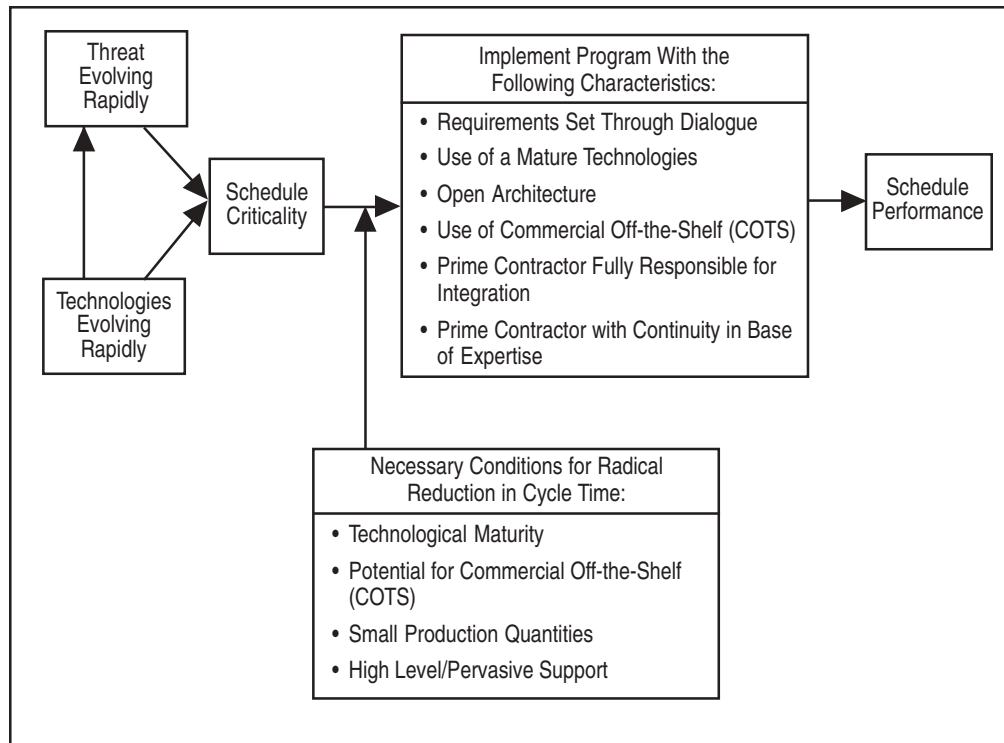


Figure 1.
A Model of Determinants with a Radical Reduction in Cycle Time

many cases where certain key technologies are evolving rapidly (thus affecting the evolving threat).

While schedule criticality is assumed for a program with a radical reduction in cycle time, there are other necessary conditions that must exist for the implementation of such a program. First, while the core technologies will be state-of-the-art, they must be sufficiently mature to avoid significant engineering development time in the schedule. Secondly, a high potential for technology insertion in the form of COTS technologies will reduce development time. Third, systems with small production quantities are advantaged by the fact that the latter stages of development and initial stages of production can

occur concurrently. Furthermore, iterative modifications can occur as a result of testing without significant cost or schedule implications. With systems requiring large production runs this is not possible. Fourth, as was the case with Guardrail, such programs require high level and pervasive support to ensure adequate funding and the budgetary stability necessary to optimize schedule.

Assuming that the necessary conditions are extant, the lessons learned from the Guardrail program suggest several important characteristics that will affect the schedule performance of a program. First, system requirements should be developed through dialogue with the technical experts (both government and contractor).

This will tend to facilitate optimization of schedule through the systematic analysis of cost, schedule, and technical performance tradeoffs. As a result, requirements with minimal benefit, or value added, but large cost and schedule implications should be minimized.

A second characteristic follows from one of the conditions for a radically reduced cycle time program. Utilizing state-of-the-art, but sufficiently mature technology, discipline must be exercised in the development process to avoid design decisions that will require significant

"The Aerial Common Sensor...is a system that stands on the shoulders of giants when one views its extraordinary

engineering development. A third characteristic will facilitate successive pre-planned product improvements and the potential to continually upgrade the system's capabilities with controlled schedule implications as the technology evolves.

This is the use of open architecture as it was successfully demonstrated in the Guardrail program. Interrelated with the use of open architecture and the use of mature technology is the maximization of the use of COTS technology. Assuming the precondition for a high level of COTS exists, maximum utilization in design decisions will tend to positively affect schedule. However, it should be noted that COTS may also result in increased integration complexities. Therefore, design decisions must optimize the use of COTS in light of other variables.

A fifth characteristic involves the prime contractor being relegated full responsibility for system integration. As GR/CS

began to deviate from this pattern there were adverse schedule implications. Integration is facilitated when responsibility is not diffused among multiple contractors and multiple government program offices.

A sixth characteristic of an effective quick reaction capability program is interrelated with the first and the fifth characteristics. Based on the lessons learned from Guardrail is the selection of a prime contractor with continuity and depth in the system specific base of expertise. Without this the resultant learning curves are such that the program schedule will be adversely affected. Furthermore, without this depth of expertise, the potential for effectively setting requirements through dialogue is greatly diminished. Similarly, the potential for effective integration is also diminished.

Clearly, other characteristics of effective radically reduced cycle time programs exist. The characteristics outlined here have been drawn from the lessons learned from the Guardrail program. Other characteristics of such programs should be the subject of future research.

CONCLUSION

The historical development of the Guardrail program summarized in this case suggests that this evolution of advanced airborne communications and electronic intelligence systems represented one of the most successful defense systems developed during the last third of the twentieth century. Based on measures of program cost, schedule, and technical performance, the sequence of Guardrail systems was exceptional. The Guardrail

systems provided commanders in the field with critical information during the Cold War, Desert Storm, and the conflict in Central Europe.

As the program proceeds in the twenty-first century, the COMINT and ELINT capabilities will be adjoined with imagery intelligence (IMINT) and measurement signature intelligence

(MASINT) capabilities. This will be the next step in the relentless succession of Guardrail systems and it will be called the Aerial Common Sensor. The Aerial Common Sensor is scheduled to be deployed in 2010, and it is a system that stands on the shoulders of giants when one views its extraordinary technological heritage.



J. Daniel Sherman received a B.S. degree from the University of Iowa, an M.A. degree from Yale University, and a Ph.D. in organizational theory/organizational behavior from the University of Alabama. In 1989–1990, he was a visiting scholar at the Stanford Center for Organization Research at Stanford University. He currently serves as the Associate Dean of the College of Administrative Science at the University of Alabama in Huntsville. He has been principal investigator (PI) or co-PI on a number of contracts with the U.S. Army. He is the author of over 40 research publications, and his research has appeared in a number of leading management journals including *Academy of Management Journal*, *Journal of Management*, *IEEE Transactions on Engineering Management*, and *Journal of Product Innovation Management*. His research interests since 1990 have focused on cross functional integration.

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